Risk in the F-22 Program

A Defense Science Board Task Force Analyzes F-22 Concurrency and Risk

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On 1 November 1994, the Under Secretary of Defense for Acquisition and Technology (USD[A&T]), Dr. Paul G. Kaminski, requested the Defense Science Board (DSB) establish a task force to "assess the degree of concurrency and risk in the F-22 program.[1]" This tasking by USD(A&T) was in response to Senate Armed Services Committee Report 163-282. The specific questions Kaminski wanted answered were:

- *Are there any areas in the F-22 program of excessive concurrency? What is the risk in each area?*
- *For any areas of identifiable high risk, are viable plans/options available that would mitigate the risk?*
- *What conclusions regarding F-22 concurrency and risk can be drawn by comparisons to existing data on previous fighter/combat aircraft programs?*

On April 17, 1995, the Chairman for the DSB Task Force on Concurrency and Risk of the F-22 Program forwarded the task force's final report. The answers, summarized or quoted from the final report, follow:

- *No areas of excessive concurrency were identified.*
- *No areas of high risk were identified. For the eight critical-technical areas the task force identified, each had specific, significant events planned for accomplishment prior to the commitment of significant production funds. The task force identified significant production funds as lot 2 contract award, which is for 12 aircraft. None of the eight critical-technical areas had "alternative, completely independent approaches for the major subsystems," but the task force concluded that "such alternative approaches were neither practical nor needed."*
- *"The Task Force found that the degree of concurrency for the F-22 program as measured by data now available is conservative when compared to other tactical fighters" (see Figure 1, recreated from the same report).*

As a general comment the report states, "The overall program appears well structured, sound, and well managed.[2]"

Having been associated with the Advanced Tactical Fighter(ATF)/F-22 programs for nearly seven years, these observations come as no surprise. Risk management has been integral to the program's management since the early days of the program and deserves significant credit for program success to date and the supportive evaluation from the Defense Science Board.

In this article I address some of the unique risk management tools and techniques applied in the program to date. It is not an all encompassing treatment of risk management on the program. To do so would require reviewing the program management in total, which would be too voluminous to publish here.

Focus on Areas of Highest Risk

First, it would be useful to define what I mean by risk. I define risk as the potential for negative, unplanned, cost, schedule, or perfor-

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mance impacts associated with a product, process, or event. Nothing is risk-free. But, our attention needs to be focused on areas of highest risk early in the development cycle; i.e., items that have a combination of a high probability of occurring and significant cost, schedule, or performance impacts as notionally depicted in Figure 2. As the program matures, however, our attention may then be focused on progressively lower levels of risk. The following paragraphs address some of the high points of ATF F-22 risk management.

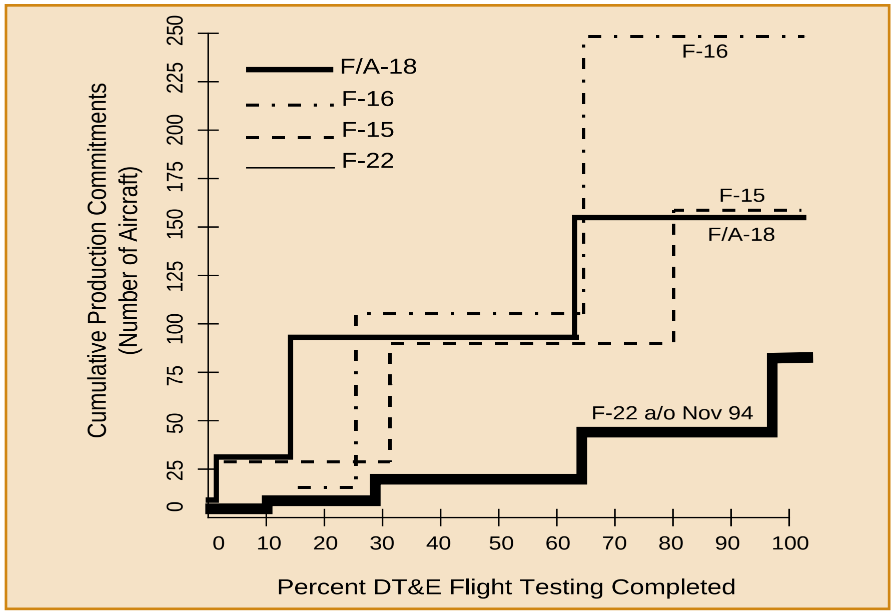
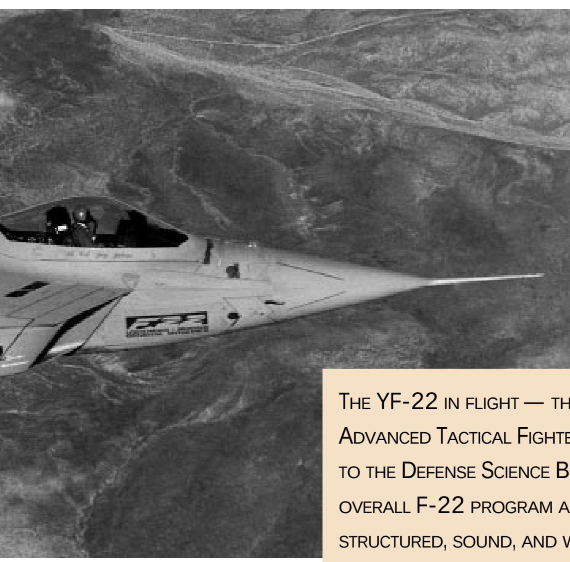


Figure 1. Concurrency Between Flight Test and Production

Concept Development/ Investigation

Phase 0, or Concept Definition/Investigation (CDI) as it was known to the ATF in the early '80s, began the risk management/reduction activities of the ATF. Program planners structured the CDI phase to identify risk areas associated with the concept of the next generation manned air-to-air aircraft. Requests for Information sent to industry provided valuable insight into schedule "long poles in the tent" and risk associated with meeting draft operational requirements that were coming together in the System Operational Requirements Document (SORD).



The YF-22 in flight — the Air Force's Advanced Tactical Fighter. According to the Defense Science Board, "the overall F-22 program appears well structured, sound, and well managed."

Additionally, government laboratories were providing significant information and experience on technologies expected to be required on the ATF, aiding identification of potential risks. According to Mr. Tom Graves, Deputy Director of the F-22, the product of the phase was a list of technologies and processes that were needed for the ATF concept to be feasible. These technologies carried varying degrees of risk. Program planners structured the Demonstration/Validation (Dem/Val) phase to address the most significant of these risks prior to entering the Engineering and Manufacturing Development Phase (EMD). Examples of such high risk areas included:

- manufacturing aircraft structure from composites;
- integrating avionics sensors to provide a composite air picture;
- demanding signature reduction in a highly maneuverable air-to-air aircraft;
- supersonic cruise in military power (supercruise); and
- improved reliability, maintainability, and supportability.

The development of a cooperative partnership between the user, represented by Headquarters, Tactical Air Command, and the developer was another significant start toward reducing risk during CDI. Much give and take would be required between the user and developer as the program matured. Flexibility would be key in delivering a product that properly balanced cost and performance.

Demonstration/Validation (Dem/Val)

In 1986, the ATF System Program Office (SPO) awarded four firm fixed price contracts: two for competitive development of the Air Vehicle (including all training and support systems), and two for competitive development of an engine. Program planners structured the contract requirements to reduce risk in what was felt to be the highest risk areas and to develop a comprehensive Preferred System Concept (PSC), which the winner would carry into EMD. Specifically, each Air Vehicle contractor team was expected to complete the following actions:

- Prototype an air vehicle and conduct reasonable flight test demos on:
  - all airframe/engine combinations (two air vehicles per team);
  - maneuverability in a low observable design fighter; and
  - supercruise.

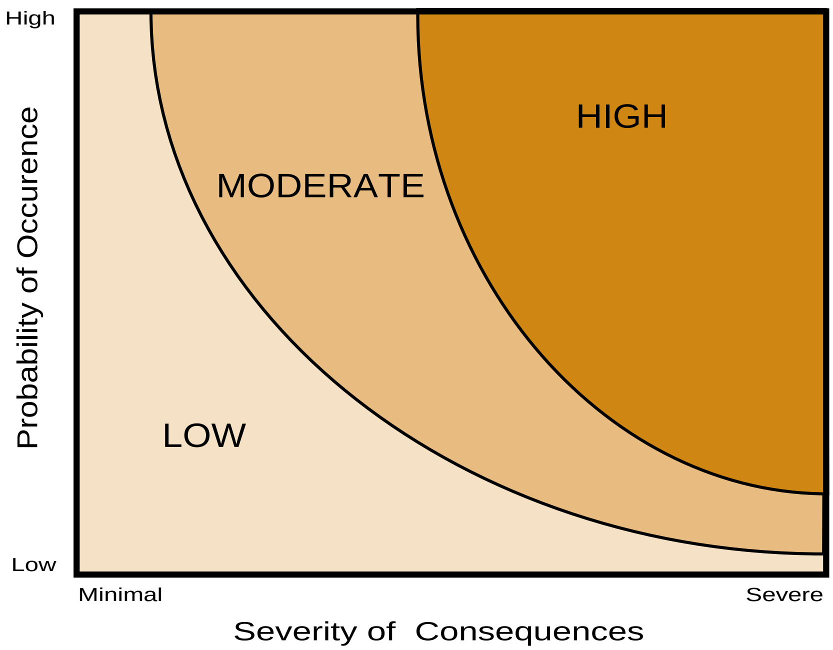


Figure 2. Degrees of Risk

- Demonstrate avionics integration/prototype through:
  - avionics ground prototype to provide preliminary integration/architecture; and
  - Avionics Flying Lab and "up and away" sensor performance.
- Demonstrate low observables of PSC through testing of full-scale pole models.
- Develop materials concept.
- Analyze system effectiveness.
- Analyze pilot effectiveness.

While these contract requirements tried to force significant risk reduction, competition provided tremendous incentive for the teams to reduce as much risk as possible during the four-year contract. The system concept with the lower risk at the end of Dem/Val would have a distinct advantage when it came time to award the "winner take all" EMD contract. As such, competition was a major risk reduction tool.

User involvement was another key to risk reduction. Dem/Val saw a number of key cost/performance/risk trades that required SORD changes or, as a minimum, user concurrence. Examples are the elimination of the Infrared Search and Track sensor, radar side arrays, and thrust vector reversing. In addition to supporting major trade decisions, Tactical Air Command representatives helped reduce risk by providing continuous feedback on design concepts, cockpit layout, tactics, and maintainability. This prevented the SPO and contractor from getting out of step with their customer and helped minimize misinterpretation of requirements.

Aside from the typical meetings and reviews, the program manager used several tools to specifically manage risk. Two such tools were: the risk reduction profile (Figure 3) and the Technical Performance Measure (TPM) (Figure 4). The risk reduction profile charted the level of risk versus time for a specific risk item. As time progressed, program technical experts conducted events designed to reduce risk through tests, analyses, demos, etc. Figure 3 reflects the technical experts' expectation of the remaining risk after each event, with the profile hopefully terminating in low- or low-moderate risk entering EMD. Risk reduction profiles provided benefit in two ways. First, developing the profile plan facilitated significant learning and helped reduce risk through understanding. Second, the profile created a logical process that could be tracked and adjusted as time progressed.

Additionally, TPMs tracked progress toward meeting performance requirements of the system and were influenced by risk reduction profiles. The example risk profile is for manufacturing low-cost thermoplastic composites. This risk reduction profile would have affected the design-to-cost TPM. If risk was satisfactorily reduced and the process incorporated into the PSC, the design-to-cost TPM would reflect the lower cost of these thermoplastic composites and a lower aircraft unit cost. You can see how broad TPMs like design-to-cost could be affected by many risk reduction efforts.

To communicate quickly with top management, the program office formatted all TPMs the same. Once the following code was broken, management could quickly assess the situation with any of the measures:

- Thick black lines represent tolerance bands, both upper and lower. Going below the lower band would indicate an unacceptable position, and increased emphasis is required to bring the parameter back within acceptable bounds. The lower tolerance level also narrows over time, in keeping with the need to reduce risk as time passes and demonstrate an ability to close in on performance requirements. The upper level is there to indicate when this area may be a good source to be traded off to the benefit of another, unacceptable risk. Performance above the upper tolerance band was viewed to have little benefit.
- The dashed line represents the objective.
- The solid line at 100 percent represents the requirement.
- The dotted line represents the plan for getting to the requirement.
- Triangles represent the current estimate of what would be attainable.
- Solid circles represent capability demonstrated (achieved) to date.

The last Dem/Val risk reduction tool I want to touch on is the involvement of Air Force laboratories. They are tremendous assets that frequently don't get the credit due for their support of acquisition programs. The labs were instrumental initially by identifying risks for the program during CDI, and in Dem/Val continued to be instrumental. Laboratory-funded research aided in reducing risks associated with manufacturing technologies; integrated avionics; the active, electronically scanned array radar; and numerous other risk areas. Laboratory efforts contributed significantly to ATF's successful Milestone II review in 1991.

Figure 5 accurately summarizes Dem/Val. The phase started with large uncertainties and the inherent risks of the unknown. These uncertainties existed due to a lack of data. As Dem/Val progressed, contractor- and (to a lesser extent) government-generated data fed the transition from the user's SORD into increasingly refined versions of the Preliminary System Specification and an increasingly defined contractor PSC capable of meeting the requirements of the system specification. The result was a match of requirements and doable technologies to baseline an executable program at EMD start.

Engineering and Manufacturing Development (EMD)

Before EMD began, the program office was refining the most significant risk reduction tool. The use of Integrated Product Teams (IPT) was going to be a contract requirement. No longer would it be acceptable for the system engineers to allocate requirements in a vacuum, designers to design in a vacuum, manufacturing to build simply as directed, and inspectors to inspect in quality after the fact. The IPT would involve all applicable functional disciplines up front so each successive step in the process of building a new system would not be reacting to the preceding step. The theory was to design a part that was suitable, manufacturable, repeatable, testable, and sup-

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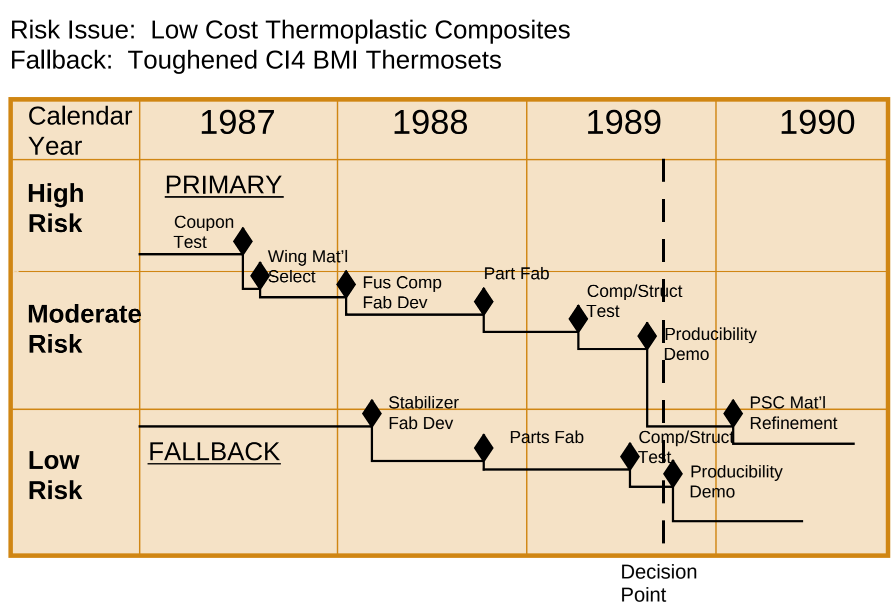
portable from the start. By doing this, we reduced the risk of redesign and the accompanying cost and schedule impacts of scrap and rework. While this required additional manpower resources up front, the payoff should be seen dramatically as the program moves into producing systems.

Not only did IPTs include all applicable contractor functionals, but also included government representatives as well. The program established one radar IPT, one airframe IPT, and one support system IPT, which consists of government and industry personnel. The contractor and government were going to be in lock step because in the eyes of the ATF leadership, if the contractor failed, the government failed. The entire contractor/government team had to be committed to the successful execution of the ATF, soon to become the F-22 program.

In looking back, Mr. Jon Ogg, Chief Engineer on the F-22, attributes much of the EMD program success to the IPTs. He believes the cooperative government-industry teaming relationship fostered effective two-way communication and a "can-do" attitude in the workforce. Armed with those two qualities, no issue has surfaced thus far that the program has been unable to resolve.

To aid the IPTs, the government and contractor developed the Integrated Master Plan (IMP) and the Integrated

Figure 3. Example Risk Reduction Profile



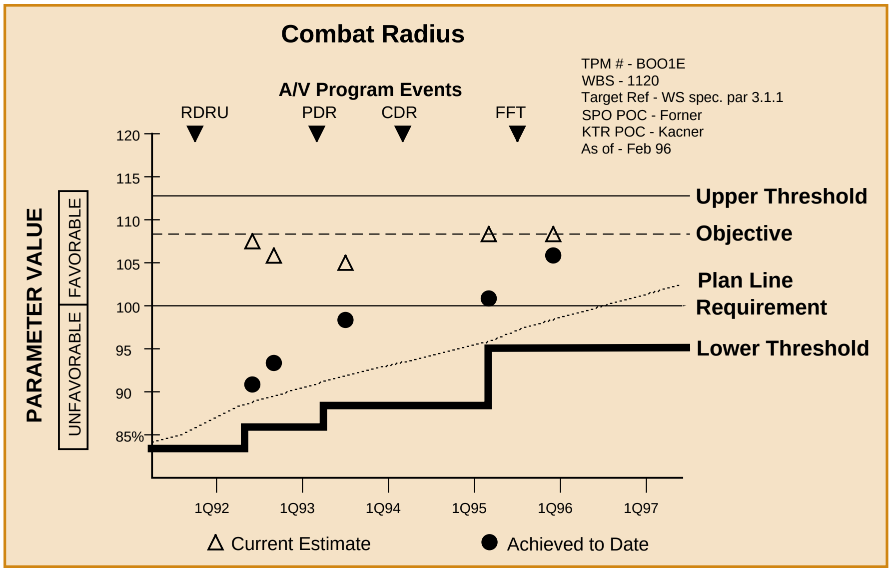


Figure 4. Technical Performance Measure

Master Schedule (IMS). The IMP is a detailed listing of accomplishments (e.g., preliminary design of the avionics bay racks) that must be completed by established milestones (e.g., Preliminary Design Review) or the milestone cannot take place. The IMP is integral to the concept of an event-driven program. If the work isn't complete, the milestone will not take place. The IMP is part of the EMD contract. And while event-driven management doesn't tie itself to a calendar, scheduling must still be accomplished so that all teams have a common target date for accomplishing tasks leading up to a milestone. This is the IMS. The IMS lays out all IMP tasks on a schedule. But the IMS is not a contractual document and, as such, can be adjusted as necessary without contracting action.

Another significant risk management change from Dem/Val to EMD was the change to a cost plus award fee contract. With competition over, some incentive was required to properly balance cost, schedule, and performance of the EMD program and ensure continued risk reduction. The Award Fee provided this incentive, and program planners structured the Award Fee Plan to incentivize the combination of a balanced approach and continued risk reduction. Particularly beneficial to risk management is the ability of the program office to tailor the subjective award fee criteria for each award fee period (a period is six months long). By focusing a portion of the award fee criteria on a particularly difficult risk, additional incentive can be placed on the reduction of that risk. Control/reduction of overhead and aircraft weight are two examples of risks previously incentivized through the Award Fee Plan. Overall, the objective of the Award Fee Plan was to balance cost, schedule, and performance. Any one that was overly emphasized would come at the expense of the others. Proper balance was, and is, the objective of the F-22.

The EMD contracts were awarded in August 1991. The task was to take the risk remaining from Dem/Val and reduce it through detail design, manufacture of test aircraft, and test. The use of TPMs was expanded, and these measures are now used to track over 250 separate metrics. It was the weight TPM that on two separate occasions flagged unacceptable trends in aircraft weight. In response, SPO and contractor personnel conducted short-term, intensive weight reduction efforts, driving weight back within acceptable bounds.

A similar problem was discovered in December 1993 through the Radar Cross Section (RCS) TPM. This resulted in a massive effort to reallocate RCS budget to some components and conduct minor redesign on others. While this was not a welcome exercise, by identifying the problem early, the cost to correct the deficiency was dramatically less than it would have been had it been caught three-four years later as would have been typical in previous programs. Ogg estimates the cost to correct this deficiency three-four years down the road would have been \$100-200M. The cost to fix in 1994 was approximately \$19M.

One other major risk reduction initiative that is paying huge dividends in EMD is the System/Software Engineering Environment (S/SEE). The S/SEE is a risk reduction tool whose development was begun in Dem/Val but came to fruition in EMD. It is a nationwide set of VAX workstations connected through a common VAX-VMS network. It provides a common environment allowing information to be shared by the geographically dispersed contractor and government facilities developing the F-22. In spite of what the name implies, its application is not limited to the software development community. According to Mr. John Howard, the government's lead engineer for the Common Integrated Processor and one of the founding fathers of the S/SEE, the S/SEE's application was originally envisioned as a software development tool only, but evolved into weapon system-wide application.

Up to now, I've discussed risk more from a technical perspective. But our processes within DoD tend to induce internal management risk, especially for a program the size of the F-22 EMD. This risk can be exacerbated by misleading publications that tend to overstate problems while ignoring or treating lightly, successes. Without adequate, accurate information reaching senior leadership, we risk making decisions on inaccurate reports resulting in undesired effects.

To mitigate this risk, it is critical for the program to keep senior leadership accurately informed. To this end, "Chief Executive Officer" (CEO) meetings were arranged. Every six months, the major stakeholders are brought together to discuss program status and issues. These stakeholders include the Secretary of the Air Force, Chief of Staff of the Air Force, Air Combat Command (ACC) Commander, Air Force Materiel Command Commander, Program Executive Officer (PEO), system program director, contractor program manager, and company CEOs and presidents. In addition to the benefits of keeping these leaders informed, I'm told it's amazing how fast a nagging program issue can be resolved when presented to this body!

The program cannot take credit for the last risk reduction tool I want to discuss. But of all the tools being used in EMD, I believe this one has the most potential for improving the F-22s' acquisition processes and reducing self-inflicted risk. In May 1995, Dr. William J. Perry, Secretary of Defense, directed the application of the principles of Integrated Product and Process Development (IPPD) in the oversight and review process.[3] This is not to be confused with the implementation of IPTs in the SPO. While the SPO approach to management changed to IPTs in 1991, oversight and review remained organized along functional lines. The result was a program office working toward a balanced product, while oversight and review organizations worked to perfect each individual functional discipline.

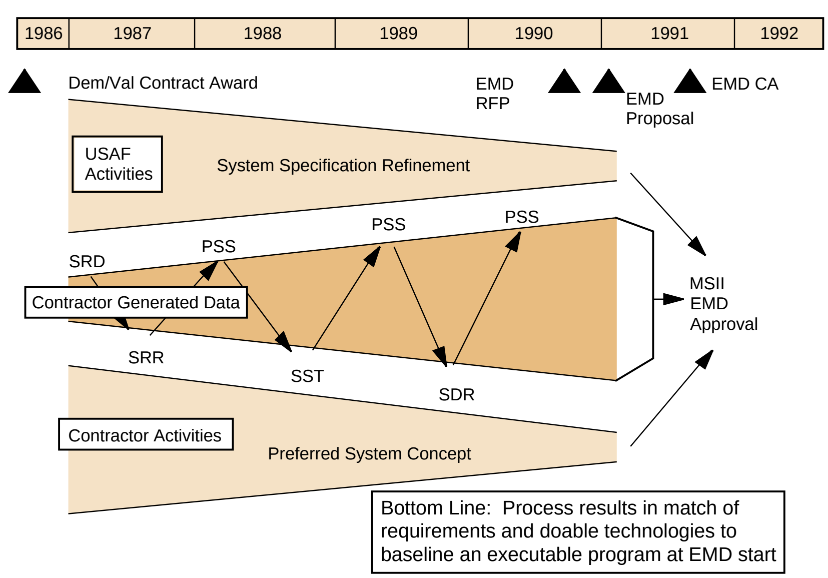
The change in philosophy required by IPPD implementation in oversight and review makes it unacceptable for staff organizations to roll in at the last second looking for a problem. Early involvement is required, and issues must be raised early in the process so they can be dealt with. All functional organizations are required to recognize the need for balance in a program and that no one area can be optimized because it ultimately comes at the expense of another. All functional team members must be committed to successfully executing the directed program, even if their area is less than perfect.

The Packard Commission recognized excessive leadership turnover in acquisition as one of the significant sources of problems. To their credit, Air Force leadership recognized the importance of this finding and allowed SPO directors to stay for significant periods of time and be promoted in position.

Some view this change as an abrogation of the oversight responsibility. I disagree. Oversight can be conducted in keeping with the principles of IPPD. In evaluating programs within their oversight realm, overseers must identify perceived problems and offer suggested improvements. The objective is to identify problems early enough to correct them so that the program has an improved chance of succeeding. Viable IPPD requires functional overseers to understand impacts on other areas and be willing to work toward a position that is the best for the program as a whole.

In compliance with Perry's direction, the F-22 established an Overarching IPT (OIPT), composed of applicable offices from the previous Defense Acquisition Board committees; the PEO; user and program director; and a Weapon System IPT (composed of action officers from key offices in the Air Staff, Secretariat Staff, J-Staff, and Office of the Secretary of Defense). Principles of IPPD are taking time to sink in, but the previous relationship with the staff that bordered on adversarial has clearly started to change. The implementation of IPPD principles can make a tremendous difference in this area. So far, our experience with IPTs in the Pentagon is encouraging.

Figure 5. ATF Dem/Val Process to Define Requirements



I would be remiss if I didn't recognize the stability of the ATF and F-22 leadership as a major contributor to risk management. The Packard Commission recognized excessive leadership turnover in acquisition as one of the significant sources of problems. To their credit, Air Force leadership recognized the importance of this finding and allowed SPO directors to stay for significant periods of time and be promoted in position.

Toward Production

The program office, in concert with the OIPT and the action officers that support it via the Weapon System IPT, is actively planning the transition to production. Risk continues to be managed during this period using previously identified tools, but we have an additional yardstick to be measured by. After the Milestone II decision, exit criteria were established for moving into the various stages of production. Like the IMP mentioned earlier, this concept is a cornerstone of the event-driven philosophy. Until the criteria are met, the program will proceed no further. Specifically, the F-22 has unique exit criteria for seven distinct production-related milestones, starting with contract award of the Pre-Production Verification Aircraft and culminating with Milestone III approval. Each of the seven milestone exit criteria requires demonstration of progressively less risk and an increasingly mature system before committing the increasingly large dollars associated with each successive production milestone. With this highly structured, event-driven transition to full-rate production, the Department of Defense will avoid committing significant production dollars to a program containing excessive risk.

Conclusion

The DSB found F-22 concurrency to be conservative relative to previous fighters, found no areas of high risk, and felt logical plans were in place to deal with risk that remains. This healthy program position can be attributed to proactive, tailored risk management, fostered by a forward-leaning leadership. Continued success cannot be guaranteed, but is certainly expected.

References

1. USD(A&T) Memorandum, "Terms of Reference – Defense Science Board Task Force on Concurrency and Risk of the F-22 Program," November 1, 1994.

2. Report of the Defense Science Board Task Force on Concurrency and Risk of the F-22 Program, April 1995.

3. SECDEF Memorandum, "Use of Integrated Product and Process Development and Integrated Product Teams in DoD Acquisition," May 10, 1995.

Since the Beginning... A Need for Weapons Acquisition

◄The Defense Systems Management College scored a hit with its newest exhibit, which debuted at the Federal Office Systems Exposition (FOSE 96) at the D.C. Convention Center, April 2-4. But the biggest hit by far was the College's choice of "Dave Cave" (a.k.a. Ed Boyd) as the resident Neanderthal. In fact the exhibit was so well received, it was unofficially named the most original of the Exposition. (Editor's Note: "Dave Cave" is a DSMC staffer whose daytime job is Visual Information Specialist, DSMC Visual Arts and Press. However, word on the street is that he's been invited to a "cast call" for the cinema production of "Flintstones II.")

Photo by Debbie Gonzalez